

## **Does external knowledge sourcing matter for innovation? Evidence from the Spanish manufacturing industry**

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## **Abstract**

This paper presents empirical evidence on the effects of external knowledge sourcing strategies on the development of both product and process innovations, and assesses the degree to which such effects are influenced by the firm's internal technological capacities. In our analysis, we consider two strategies for acquiring external knowledge (buying and cooperating) and two types of external sources (industrial agents and scientific agents). The analysis is based on a sample of 1,329 manufacturing firms active in innovation activities taken from the Spanish Survey of Technological Innovation 2004. We find that the effects of the knowledge sourcing strategies differ significantly across innovation types (product or process innovation). In addition, our results indicate that although internal R&D activities are associated with a greater use of external scientific knowledge sources (through cooperation), they do not seem to promote their exploitation for innovation development, that is to say, they do not have synergistic effects.

## **1. Introduction**

The role of external knowledge sources as determinants of innovation has been repeatedly emphasized in the literature within a range of theoretical approaches. Evolutionary theorists, for instance, consider that innovation involves a process of continuous interactive learning between the firm and the various agents surrounding it (Lundvall,

1992; Edquist, 1997; Breschi and Malerba, 1997). Similarly, innovation network theorists (Håkansson, 1987; Baptista and Swan, 1998; Cooke and Morgan, 1998) maintain that firms rarely innovate on their own, and that the introduction onto the market of new products and processes largely depends on the firm's ability to build strong links with external agents. Chesbrough, through his *open innovation model*, also points to the importance of external ideas for the innovation process and even suggests that internal R&D is no longer the strategic asset it once was (Chesbrough, 2003).

Nevertheless, some researchers have warned about the risk of overestimating the role played by external knowledge sources, arguing that in many industries, innovation efforts are not only made by firms themselves, but are generated in house (Nelson, 2000). The studies conducted by Oerlemans et al. (1998) in the Netherlands and Freel (2003) in the UK, show that the firm's internal resources are the main determinants of their innovation performance, and that the creation of external networks has only a limited impact. Some authors have even suggested that in attempting to decentralize and outsource R&D activities firms may weaken their core competences (Coombs, 1996).

On the other hand, and from a more integrative perspective, some works point out that external and internal knowledge acquisition can be complementary activities in the firm's innovation strategy. These authors maintain that the effect of external knowledge sources on innovation performance, although important, depends on the internal capabilities of the firm. Rothwell (1992), for example, highlights that links to external scientific and technical knowledge sources are effective only if the organization is well prepared and open to external ideas, and has skilled scientific and technical staff. In line with this thinking, Cohen and Levinthal's (1989, 1990) concept of 'absorptive capacity' has gained influence in recent years. This concept places special emphasis on the firm's pre-existing knowledge in the tasks of identifying, assimilating and exploiting external knowledge.

Based on this concept, it has been argued that not only do the firm's internal efforts to create new knowledge encourage the use of external knowledge sources, they also increase the firm's ability to exploit these sources efficiently in the development of new products and processes. Thus, the greater the internal capabilities of the firm, the greater are the effects of the different external knowledge acquisition strategies on innovation performance.

However, the above argument, though widespread, lacks sound empirical foundation. The few empirical analyses of these relationships have produced mixed findings. Cassiman and Veugelers (2006), for instance, found that internal R&D and external knowledge acquisition were complementary with respect to influencing innovation performance, while Laursen and Salter (2006) found evidence of a substitution effect between internal research and development (R&D) and external knowledge search activities.

This paper provides empirical evidence on the effect of the external knowledge sourcing strategies adopted by firms, on the development of both product and process innovation, and assesses to what extent this effect is influenced by the firm's internal technological capabilities. Extending Cassiman and Veugelers (2006), we investigate the effects of two strategies for acquiring external knowledge (buying and cooperating) and two types of external sources (industrial agents and scientific agents). Also, we examine the effects of these activities in relation to the particular industry in which the firm operates, considering two sectoral categories: science-based firms and supplier-dominated firms. This paper aims to assess the real value of external knowledge sources as the determinants of innovation by integrating various external sourcing strategies, the firm's internal capabilities and the industry characteristics, into the same analytical framework.

The analysis of external knowledge sourcing strategies uses firm level data from the Spanish innovation survey. Spain is a technology follower country, demonstrated by its

science and technology indicator scores, which are among the lowest in the EU. For example, total expenditure on R&D in relation to GDP is half of the EU average, and Spain's productive sector is characterized by a concentration of traditional low-technology sectors and medium and small enterprises with low R&D expenditure (Castro and Fernández, 2006). Most firms in Spain—including innovative ones—are at a lower technological level than their international competitors (Molero and Buesa, 1996), therefore, it is to be expected that a high percentage of the product innovations introduced in the marketplace consist of small incremental improvements. Another feature of the Spanish innovation system that is distinctive, is the great importance of the public sector, which constitutes the principal source of knowledge. In 2004, this sector, comprised of universities and public research organizations, accounted for 45% of total national expenditure on R&D and employed more than 76% of the researchers in Spain. This is atypical for Europe as a whole; in other European countries almost half of all researchers are employed by private firms. In addition, cooperation between firms and research centres in Spain is lower than the European average according to the 4<sup>th</sup> Community Innovation Survey (CIS-4).

Bearing in mind these features of the Spanish innovation system, it is hoped that the results provided in this paper will facilitate comparison and establish differences in innovation patterns with the technologically leading countries, which traditionally have been the focus of this type of analysis. Also, given that one of the priorities of Spanish innovation policy is to intensify the relationships between firms and public research institutions (European Commission, 2001), the results of the present study, which examines the effects of cooperation and other external knowledge sourcing strategies on firms' innovative performance, should have important implications for public policy.

The paper is organized as follows: Section 2 provides a brief review of the literature. Section 3 describes the methodological aspects of the empirical study, the data, the measures of the variables and the econometric specifications. Section 4 presents the results, and Section 5 offers some conclusions from the study.

## **2. Theoretical and empirical background**

Many current economic theories on and approaches to innovation, to a greater or lesser extent, hold that individual firms are seldom capable of innovating independently and that a firm's internal technical capabilities are insufficient to cope with the challenges of the global market. Likewise, studies in the field of business management indicate that the search for new product ideas, new forms of organization and/or solutions to existing problems goes beyond the firm's boundaries in exploring available capacities in other firms or institutions. In theory, a wider and more diverse search strategy will provide access to new opportunities and enable the firm to build new organizational competences based on the integration of complementary knowledge sets from external agents (Teece, 1986; March, 1991).

There is solid empirical evidence that the use of external knowledge sources is both an important theoretical issue and a growing phenomenon. In most OECD countries, for instance, the share of business expenditure on external R&D has gradually increased since the 1980s. In countries such as the UK and Germany, business expenditure on external R&D doubled in proportion to total expenditure on R&D, over a ten year period (Howells, 1999; Bönte, 2003). Another clear indication of the higher use of external knowledge sources is the increasing number of inter-firm partnerships. In this

respect, Hagedoorn (2002) shows that the number of inter-firm R&D partnerships recorded in the MERIT-CATI database, increased from 10 during most of the 1960s to nearly 600 by the end of the 1990s. This increased use of external knowledge sourcing has been attributed to the increasing complexity and interdisciplinary nature of the R&D process combined with reduced technology life cycles and the development of a technology knowledge market (Howells et al., 2003). These trends have been accompanied by a decrease in the number of internal R&D departments and an erosion of the strategic advantage of in-house R&D activities (Chesbrough, 2003).

Linked to these trends, a theoretical and empirical literature has developed on the factors determining external knowledge acquisition and its effects on firms' innovative performance. Most of this literature focuses on the choice between external sourcing and internal development, the so-called *make or buy* decision (Veugelers and Cassiman, 1999; Beneito, 2003). A traditional approach to the analysis of this issue derives from transaction cost theory, which suggests that in the presence of asset specificity, uncertainty and opportunistic behaviour, transactions take place more efficiently and hierarchically within the firm than via the market (Williamson, 1985). Using the concepts of market and hierarchy, several authors have examined the economic arguments for outsourcing versus in-house R&D (Teece, 1988; Kay, 1988; Pisano, 1989, 1990). Following this line of inquiry, external knowledge sourcing and in-house R&D are considered as substitutes and, in considering costs and risks, firms opt for either a make or a buy strategy. Firms are thus confronted with the management of internal and external innovation strategies and must decide which technologies to develop in-house and which to source externally. The later resource-based approach, however, emphasizes that competency development requires a firm to have an explicit

policy on the use of external knowledge sources as an opportunity to learn, rather than as a way to minimize costs (Robins and Wiersema, 1995). This suggests that external knowledge should be used to complement rather than substitute for internal R&D.

Mowery (1983) found perhaps the first evidence of complementarities between external knowledge sourcing and internal knowledge development. In a study of the contracting behaviour of major independent R&D laboratories during the period 1900-1940, Mowery (1983) and Mowery and Rosenberg (1989) extended the transaction cost perspective by suggesting that demand for extramural contract R&D was greater when firms possessed the expertise necessary to identify their needs and to utilize external research. Analysis of the complementarity between innovation strategies was extended by Cohen and Levinthal's (1989, 1990) seminal work. Building on Mowery's work in particular, these authors emphasized that a firm's knowledge base enhances the effectiveness of external technology sourcing in providing the means to understand and utilize the information acquired. They suggested that in-house R&D activities played the dual role of generating innovation and improving the firm's absorptive capacity, that is, the ability of the firm to identify, assimilate and exploit the knowledge generated by competitors and extra-industry sources (Cohen and Levinthal, 1990). Several studies followed on the relationships between external and internal know-how or, in strategic terms, between external knowledge sourcing and in-house knowledge development. Arora and Gambardella (1990, 1994), for instance, found that firms that conduct more R&D have larger numbers of external links (equity participations, contractual and non-contractual agreements, acquisitions) aimed at acquiring technology. Lowe and Taylor (1998) found a similar relationship between in-house R&D and technology purchase through licence agreements, and Freeman (1991) points out that firms with R&D



departments tend to use external knowledge sources intensively. There is evidence of an inverse relationship whereby external knowledge acquisition encourages internal R&D activities. Veugelers (1997), for example, illustrates that external sourcing can often stimulate internal R&D activity, at least for firms with R&D departments, while Becker and Dietz (2004) found evidence that cooperation with external agents enhances in-house R&D intensity.

Thus, there is empirical evidence on the importance of the firm's knowledge base for enabling the firm to identify and acquire external knowledge and, vice versa, on the role of externally acquired knowledge in enhancing internal R&D activities. On balance, however, the literature is not conclusive about the complementarity between internal and external technology sourcing with respect to the impact on firm's innovative performance. Such complementarity or synergy is assumed to exist if the implementation of one strategy increases the marginal returns from another (Milgrom and Roberts, 1990), for instance, if performing in-house R&D activities enhances the effectiveness of externally acquired technological knowledge for innovation. There has been little empirical analysis along these lines, and the findings from the few studies conducted are mixed. Laursen and Salter (2006) examine the relationships between the number of the firm's external knowledge sources (which they term 'external search breadth') and its innovation performance. They find an inverse U-shaped relationship, indicating that the breadth of the firm's external search strategies is beneficial only up to a certain level. They also find that internal R&D negatively moderates the relationship between external knowledge sources and innovation performance, suggesting the existence of a substitution effect between openness to external search activities and internal R&D. In contrast, Cassiman and Veugelers (2006) find that in-house R&D and

external knowledge acquisition are complementary with respect to the impact on innovative performance. They analyse both complementarity among innovation activities and the contextual variables in the firm's strategy that affect this complementarity. They conclude that the extent to which the firm relies on more 'basic' types of know-how (i.e., the use of universities and research centres as information sources for innovation) affects the strength of the complementarity among innovation activities.

In this paper, we follow a similar approach in analysing the effect of different external knowledge sourcing strategies on firm's innovative performance and exploring the relationships between these strategies and in-house R&D. Our study extends previous research in three ways. First, whereas Cassiman and Veugelers (2006) focus on *make* and *buy* strategies, we include an additional knowledge sourcing strategy: *cooperation*. Although the theoretical literature drawing on transaction cost economics, considers cooperation to be a 'hybrid' of hierarchical transactions within firms (*make*) and arms-length transactions in the market place (*buy*), several authors see cooperation as a strategy in its own right, which should be treated as a distinct form of economic organization used for exchanging resources and value-creating assets (Chesnais, 1996). Cooperation allows firms to share costs and uncertainty, to realize economies of scale and scope, to exploit synergies from complementarities and even to win government support (Croisier, 1998; Becker and Dietz, 2004; Veugelers and Cassiman, 1999). Moreover, this strategy may be less vulnerable to transaction costs than contracting, especially when the technology is complex (Shing, 1997). In addition, we distinguish between cooperation with industrial agents and cooperation with scientific agents. This distinction is important as knowledge from these types of agents tends to be different in nature and therefore may

not only serve different purposes, but also may relate differently to a firm's internal capabilities. For instance, Cohen and Levinthal (1990) suggest that the knowledge drawn from extra-industry sources such as government and university labs, is typically less targeted to a firm's requirements and priorities than that drawn from materials and equipment suppliers, and therefore requires more expertise from the firm to exploit it efficiently.

Second, most of the existing studies on the effects of external knowledge sourcing focus on 'disembodied' knowledge acquisition strategies, such as R&D contracting or licensing agreements. However, there are other means within the firm's technology strategy whose role in innovation is by no means negligible, for example, the 'embodied' purchase of machinery and equipment (Evangelista, 1999; Beneito, 2003). CIS-4 shows that half the European firms reporting product or process innovation do not conduct in-house R&D, while approximately 70% engage in machinery, equipment and software acquisition. In the particular case of Spain, according to aggregate industrial data for 2004 published by the National Institute of Statistics (INE) approximately 74% of innovative firms engage in machinery and equipment acquisition, accounting for 33% of their innovation expenditures. We therefore include in our analysis, acquisition of technology embodied in machinery and equipment as another external knowledge sourcing strategy.

Third, in our analysis we consider the possible effects of industrial dynamics on the use and exploitation of external knowledge sources. A rich and heterogeneous tradition of studies in industrial economy shows that innovation differs across sectors in terms of characteristics, sources, actors, links and relationships among actors, and the boundaries

of the process (Malerba, 2005). As a consequence, several sectoral classifications have been developed, ranging from the traditional distinction between high and low R&D-intensity sectors (widely used in OECD and EU international studies), to the Schumpeterian-type distinction based on differences in market structure (Schumpeter Mark I and Schumpeter Mark II). Other differences across sectors are related to such characteristics as technological opportunity and appropriability conditions, which shape the technological regime (Nelson and Winter, 1982). All these characteristics can influence the use of external knowledge sourcing. Klevorick et al. (1995) for example, indicate that the lower the level of technological opportunity in an industry, the lower the firm's incentives to draw on external knowledge sources, and therefore the higher its reliance on internal sources. On the other hand, a low level of appropriation might cause the firm to reduce its in-house investment in R&D because it cannot fully internalize all the benefits from its investment (Spence, 1984). Cohen and Levinthal's (1990) response was to suggest that a low level of appropriability could promote in-house R&D activities to develop sufficient absorptive capacity to capitalize on the *spillovers* in the industry. To control for these potential variations, here we adopt Pavitt's (1984) taxonomy of the sectoral patterns of innovation, which classifies firms in terms of the appropriability mechanisms and technological knowledge sources used to develop innovation activities.

### **3. Data and methodology**

#### *3.1. Data and Sample*

The data for the empirical analysis come from INE's Technological Innovation Panel (PITEC), and Spain's Science and Technology Foundation (FECYT) and Foundation for Technical Innovation (COTEC). PITEC is a panel survey, based on the

Technological Innovation in Companies Survey (TICS), inscribed in the CIS, and designed to collect detailed information on innovation activities in Spanish firms in all sectors of the economy. The data are available in a set of coordinated yearly files for 2003 and 2004.

We considered TICS data for 2004, which provides information on the innovative behaviour of Spanish firms during the period 2002-2004.<sup>1</sup> The final database for 2004 includes 8,800 manufacturing and service companies; we use data on the 4,445 manufacturing companies,<sup>2</sup> across 31 sectors based on Spain's National Classification of Economic Activities (CNAE).

[Insert table 1 about here]

Table 1 shows the sample distribution by number of employees and types of innovation activities. PITEC comprises two main samples: a sample of firms with 200 or more employees, which accounts for 86% of all firms with 200 or more employees according to data from the Central Business Directory (DIRCE), and a sample of firms with intramural R&D expenditure, which accounts for 56% of all firms engaged in in-house R&D, according to data from the Research Business Directory (DIRID). These samples are thus very representative of these populations (big firms, and firms with intramural R&D). In 2004, a sample of small firms (less than 200 employees) and external, but no internal R&D expenditure, and a sample of small firms with no innovation expenditure, were included.

In the TICS survey, firms are asked whether they had introduced a new product or process, or whether they had ongoing or abandoned innovation activities during the period 2002-2004. A positive answer to one of these questions classifies them as

*innovators*. We used this selection criterion to restrict our analysis to the subsample of *innovator* firms. This decision is mainly driven by the design of the questionnaire itself, because only the *innovator* firms have to answer the full questionnaire, including those questions related to cooperation with external agents. After deleting observations with missing values, we were left with a sample of 3,311 firms. We checked that the records excluded for missing values did not differ in some observable dimensions from the final sample.

### *3. 2. Sectoral Classification*

Section 2 refers to several studies in the field of industrial economics, which show that the effect of internal and external knowledge sources on innovation may be determined by industrial dynamics (Malerba, 2005). In order to control for these potential variations, we adopt Pavitt's (1984) taxonomy of patterns of technological change, which classifies firms as supplier-dominated, scale intensive, specialized supplier and science-based. Although this can lead to some simplification, its applicability as a criterion for classifying firms has been demonstrated in several studies (Arundel et al., 1995; Cesaratto and Mangano, 1992).

We focused on supplier-dominated and science-based firms for three reasons. First, these sectoral categories include those firms for which the relative importance of the two types of external knowledge sources considered here (scientific and industrial sources) is more clearly distinguishable. Pavitt (1984), for instance, suggests that in supplier-dominated firms (textiles, clothing and fur, furniture, etc.), technological knowledge is mainly embodied in the machinery, equipment and capital assets produced by other sectors, while in science-based firms (pharmaceuticals, electronic components, spacecraft), the main sources of knowledge are the firms' internal R&D activities and scientific research carried out by universities and public research institutions. Second,

analysis of these sectoral categories allows us to examine whether, as Cassiman and Veugelers (2006) suggest, a firm's reliance on more 'basic' types of know-how affects the degree of complementarity between innovation strategies. Third, these categories substantially differ in terms of level of technological opportunity (Marsili, 2001), which could affect the use of external knowledge sources. Thus, we can expect higher use of external knowledge sourcing strategies by science-based than supplier-dominated firms.

We selected a total of 1,329 firms from the group of manufacturing companies within the supplier-dominated and science-based categories. The distribution of the final sample is shown in Table 2. The first two columns (sample, % sample) show the number of firms by industrial sector and the percentage in the total sample of the respective sectoral category (supplier dominated or science-based firms). The last two columns (population, % population) show the population of innovator firms by industry sector and the percentage in the population of the respective sectoral category.

[Insert table 2 about here]

### *3.3 Measures*

#### *3.3.1 Dependent variables*

According to Oerlemans et al. (1998), the effects of internal and external resources on firms' innovation outcomes vary according to the industry in which the firm operates and the type of innovation developed. The literature on the sources and determinants of technological change has traditionally focused on the study of product innovation, and neglects process innovations (Reichstein and Salter, 2006). In our analysis we distinguish between these two types using dichotomous variables - related to product

innovation (PRODIN) and process innovation (PROCIN) - based on the responses to two questions in the survey that enquire about whether the firm has introduced new or significantly improved products or processes during the period 2002-2004.

### 3.3.2 Explanatory variables

The first group of explanatory variables relates to the different external knowledge acquisition strategies. Following Veugelers (1997), we distinguish between bought-in knowledge (*BUY*) and knowledge acquired through cooperation (*COOPERATION*). Within the *BUY* strategy, we further distinguish among external R&D (*ERD*), technology embodied in machinery and equipment (*EQ*), and intangible technology in the form of patents, trademarks, software, etc. (*TECNO*). These strategies are measured using dummy variables that take the value 1 if the firm has used the strategy during the period 2002-2004 and 0 otherwise. The database provides information on expenditure on these activities, for 2004. We decided on dichotomous variables because they refer to the same period as the dependent variables, thus avoiding relating knowledge sourcing strategies in 2004 with innovations in previous years.

Generally speaking, R&D outsourcing is associated with product innovation, particularly in the case of science-based firms, and technological knowledge embodied in machinery and equipment is traditionally related to process innovation, particularly for supplier-dominated firms (Von Hippel, 1988). The effect of intangible technology acquisition has been relatively under researched, although a positive relationship between this variable and the firm's innovative performance is likely.

Strictly speaking, cooperation is not purely related to external knowledge acquisition because it builds on externally supplied knowledge and firm's internal capacities.



Cooperation can take several forms depending on the characteristics of the partners, the organizational structure of the relationship, the scope of the project, the time horizon, etc. (Howells et al., 2003). This has resulted in a number of taxonomies for different modes of inter-firm relationships. We can make a basic distinction between equity-based joint ventures (JV) and contractual partnerships, such as joint R&D and joint development agreements. JVs are organizational units created and controlled by two or more parent-companies, which increase the organizational interdependence of the parent companies. Contractual agreements refer to technology and R&D sharing among two or more institutions, in combination with joint research or joint development projects (Hagedoorn, 2002). We focus on contractual cooperation, for which we have information from TICS. We drew specifically on the responses to the questions about cooperation with external agents for R&D and innovation activities during the period 2002-2004. Based on previous classifications relating to the nature of external knowledge sources (Klevorick et al., 1995), we constructed two variables—*CI* and *CNI*—with the aim of reducing the number of variables in the regression analysis. The first relates to cooperation with industrial agents (clients, suppliers, competitors and sister companies); the second relates to cooperation with scientific agents or with agents outside the industry chain (commercial laboratories/R&D firms, universities, public research institutions and technological centres). These variables are measured on an ordinal scale (range 0-4) according to the number of collaborative agents in each category. The Cronbach alpha coefficients are 0.68 (CI) and 0.77 (CN).

The effect of cooperation with external agents on innovation in firms has been extensively examined in the literature. On the one hand, these studies identified sectoral variations associated with greater relative importance of cooperation with scientific agents for science-based firms, and with industrial agents for supplier-dominated firms (Freel, 2003;

Oerlemans, 1998). On the other hand, although universities and R&D institutes have traditionally been recognized as key actors in new product development, their role in process innovation is far from clear (MacPherson, 1997; Reichstein and Salter, 2006).

The second group of explanatory variables relates to the firm's internal technological capabilities. We include two variables traditionally considered to be indicators of firms' efforts to create and assimilate new knowledge. The first refers to the development of in-house R&D. The 2004 TICS database reports whether the firms carried out continuous or occasional in-house R&D activities in 2002–2004. Based on this, we built the variable *IRD*, which takes the value 0 if firms did not undertake internal R&D activities in 2002–2004, 1 if they occasionally engaged in R&D activities, and 2 if they had continuous in-house R&D. We chose this measure rather than a dummy variable as we consider it to be a better proxy for the firm's R&D stock and therefore a better indicator of technological capabilities. The second variable, *TRAINING*, refers to efforts made to train those staff involved in the implementation of a product or process innovation. This is a dummy variable that takes the value 1 if the firm has carried out training during the period 2002–2004 and 0 otherwise.

Both internal R&D and innovation related training increase the firm's organizational knowledge base and its ability to utilize this knowledge (Caloghirou et al., 2004). Empirical studies demonstrate the importance of internal R&D as a determinant of product innovation, but are inconclusive about the influence of this variable on new process development. Freel (2003), for instance, found that internal R&D expenditure by science-based and supplier-dominated firms was not associated with process innovation, whereas Reichstein and Salter (2006) found evidence in favour of a significant and positive relationship between these variables. Likewise, there is no consensus on the

influence of investment in staff training on new process development or the launch of new products.

On the other hand, it has been suggested that a firm's internal capacities condition the effects of external knowledge sourcing strategies on innovative performance. Thus, Harabi (1995) and Klevorick et al. (1995) argue that only those firms with a critical mass of knowledge are able to use the knowledge that exists in their environment to expand their innovation capabilities. Also, Cohen and Levinthal (1989, 1990) refer to the two faces of R&D, in terms of the different effects of internal R&D activities on the firm's innovation performance. This suggests that there is a direct and positive effect, since these activities engender new knowledge, which can be used for the development of new or enhanced products and/or processes. In addition, there is an indirect effect resulting from the increase in the firm's absorptive capacity, which facilitates the acquisition and exploitation of external knowledge, at least if the firm is willing to overcome the 'not-invented-here' syndrome (Katz and Allen, 1982; Veugelers and Cassiman, 1999; Laursen and Salter, 2006). This effect is particularly relevant for scientific or technological knowledge whose absorption and use will require greater efforts on the part of the firm. This applies to knowledge acquired through cooperation with scientific agents or R&D outsourcing.

It would be expected, then, that the development of in-house R&D activities, especially if they are continuous, would be likely not only to increase the potential to generate product and process innovations, but also to emphasize the role of external scientific and technological knowledge as determinants of innovation. This implies that the greater the firm's internal capacities, the greater the effect of R&D contracting and cooperation with scientific agents on the firm's innovative performance.

We also include as a control variable a measure for firm size (*SIZE*). Although the importance of size as a determinant of innovation has been extensively analysed, it is difficult to determine *a priori* its real influence. The Schumpeterian hypothesis holds that, as large firms own the necessary resources (infrastructure, financial resources, production and marketing capabilities, R&D) to cope with the risks associated with innovation processes, they are more likely than their smaller counterparts to engage in innovative activities. Some recent empirical works have found evidence supporting this hypothesis (Freel, 2003; Reichstein and Salter, 2006). Other studies, however, have produced contrasting results. Acs and Audretsch's (1988) work, for instance, shows that small and medium sized enterprises (less than 250 employees) are more innovation-intensive than larger firms, due, amongst other reasons, to their lower degree of rigidity when faced with innovations (Caloghirou et al., 2004; Cohen, 1995).

In this analysis *SIZE* is measured as the logarithm of the firm's sales volume in 2004. Logarithmic specification has been acknowledged to be the most appropriate technique for measuring firm size and testing the Schumpeterian hypothesis (see Kamien and Schwartz, 1982; Cohen, 1995).

### *3.4 Econometric specifications and selection bias control*

Although our study focuses on the effects of different external knowledge sourcing strategies on the firm's innovative performance, restricting the analysis only to *innovator* firms could lead to selection bias. To address this potential problem we used two-part logit models (Manning et al., 1987). In the first stage of our analysis, we ran a general (*selection*) model using all available observations and considering the independent variable *INNOVATOR* to indicate whether or not the firm was innovative.

This allowed us to calculate the probabilities of each firm becoming an innovator, (*PINNOVATOR*). We ran second-stage models (*main models*) in which the dependent variables were whether the firm had introduced a new or improved product or process in the market during the period 2002-2004. In these second-stage models non-innovator firms were dropped from the analysis, but the *PINNOVATOR* variable was included as an additional independent variable. According to Haas and Hansen (2005), this procedure is appropriate when the dependent variable in the selection model is observed rather than estimated, and more appropriate than a Heckman selection model since the dependent variable in the main model is binary rather than continuous.

The econometric specification of the first-stage model is as follow:

$$INNOVATOR_i = \alpha_0 + \alpha_1 SIZE_i + \alpha_2 EXPORT_i + \alpha_3 GROUP_i + \alpha_4 FAC \cos t_i + \alpha_5 FACknow_i + \alpha_6 FACmark_i + \alpha_7 FACneed_i$$

The *INNOVATOR* variable is a dummy variable that takes the value of 1 if the firm is an innovator and 0 otherwise. Consistent with the literature (Cassiman and Veugelers, 1999), we included as explanatory variables, firm size (*SIZE*), export orientation (*EXPORT*) and belonging to a group (*GROUP*), as well as industry dummies to capture future demand and technological opportunity. We also included four variables measuring the obstacles to innovation: cost (*FACcost*), lack of technological/market information (*FACknow*), lack of demand (*FACmark*) and need for innovation (*FACneed*). For a detailed description of these variables, see Appendix A.

The second stage models were estimated using the variables described in Section 3.2. and including the *PINNOVATOR* variable. We can define the following specifications:

$$INNOV_i^d = \alpha_0 + \alpha_1 ERD_i + \alpha_2 EQ_i + \alpha_3 TECNO_i + \alpha_4 CI_i + \alpha_5 CNI_i + \alpha_6 SIZE_i \quad \textbf{(model. 1)}$$

$$INNOV_i^d = \alpha_0 + \alpha_1 ERD_i + \alpha_2 EQ_i + \alpha_3 TECNO_i + \alpha_4 CI_i + \alpha_5 CNI_i + \alpha_6 IRD_i + \alpha_7 TRAINING_i + \alpha_8 SIZE_i \quad (\text{model. 2})$$

$$INNOV_i^d = \alpha_0 + \alpha_1 ERD_i + \alpha_2 EQ_i + \alpha_3 TECNO_i + \alpha_4 CI_i + \alpha_5 CNI_i + \alpha_6 IRD_i + \alpha_7 TRAINING_i + \alpha_8 SIZE_i + \alpha_9 IRD_i * ERD_i + \alpha_{10} IRD_i * CI_i + \alpha_{11} IRD_i * CNI_i \quad (\text{model. 3})$$

where  $i = 1, \dots, N$  (number of occurrences); and  $d = PRODIN, PROCIN$ .

In the first model, we analyse the effect of external knowledge sources on a firm's innovation performance, regardless of its internal technological capabilities. In the second model, we include *IRD* and *TRAINING* as additional explanatory variables in order to determine to what extent internal capabilities influence the innovation outcome and to ascertain their impact on the effects of external knowledge sourcing. To explore this aspect further, model 3 includes three interactive terms, derived by multiplying *IRD* (moderating variable) by the *ERD*, *CI*, *CNI* (moderated) variables.<sup>3</sup>

Each of these three models was estimated for both of the two sectoral classes analysed, employing 'new or significantly improved product introduction (PRODIN)', and 'new or significantly improved process introduction (PROCIN)' as the dependent variables. This analysis yielded 12 logistic equations, which, based on the dichotomy of the dependent variables, were estimated using binary logistic regression.

## 4. Results

### 4.1 Descriptive results

Tables 3 and 4 present the basic statistics for the variables in the regression analysis, and their correlation coefficients.

[Insert table 3 about here]

[Insert table 4 about here]

In line with Pavitt's (1984) conclusions, our findings show that supplier-dominated firms innovate more in processes and science-based firms innovate more in products. The descriptive statistics also show some differences in terms of the use of external knowledge sourcing strategies, especially cooperation. First, science-based firms cooperate more than supplier-dominated firms with external agents, although the level of cooperation is still generally below the European average.<sup>4</sup> Thus, cooperation is more widespread in sectors of higher technological intensity, as suggested by Hagedoorn (1993) and Wang (1994). In partnerships, cooperation with scientific agents is the most frequent form of collaboration for science-based firms, but, surprisingly, cooperation with industrial agents is not proportionately greater in the case of supplier-dominated firms. These results coincide with those in Castro and Fernández (2006), and demonstrate that in general Spanish firms engage in low levels of cooperation, and that those firms that collaborate are more likely to choose scientific institutions as partners. If we look at the individual categories, we can see that supplier-dominated firms mainly cooperate with suppliers of machinery and equipment and science-based firms mainly cooperate with universities.

If we consider knowledge acquisition as a market transaction (*buy* strategy), science-based firms tend towards R&D outsourcing, while supplier-dominated firms tend to draw on the 'embodied' purchase of machinery and equipment. These results largely coincide with the expected patterns.

Other differences across the sectoral categories analysed relate to the development of in-house R&D activities. Our findings show that 93% of science-based firms conduct in-house R&D, 80% of them continuously, while the same proportions for supplier-dominated firms are 76% and 58% respectively.

The correlation matrix reveals some interesting findings. In the two sectoral categories analysed, internal R&D activities show strong correlation with product, but not process innovation. Process innovation, instead, is mainly associated with the purchase of machinery and equipment, especially in supplier-dominated firms.

On the other hand, internal R&D activity is positively related to cooperation strategies, and especially cooperation with scientific agents. This latter result may be an indication of the twofold effect of internal R&D, that the greater the effort on this activity, the greater the ability of the firm to identify and use sources of scientific knowledge. This is not to say that firms that do not cooperate with scientific agents fail to perform in-house R&D, but rather that those that do cooperate are generally more active in this respect (Bayona et al., 2002). However, this positive relationship is not observed in the case of R&D outsourcing. In fact, the correlation coefficient for the *ERD* and *IRD* variables is negative and significant for supplier-dominated firms. This suggests that R&D outsourcing tends to diminish if the firm conducts in-house R&D, especially in a continuous way.

Finally, in contrast to some studies (Martínez-Ros, 2000; Reichstein and Salter, 2006), we find that product and process innovation are not significantly correlated. Indeed, the correlation coefficient between these variables is negative although not significant, for supplier dominated-firms. It seems that for Spanish innovative firms, product and process innovation are independent of each other, and are associated with different knowledge sourcing strategies.

#### *4.2 Regression analysis*



The parameters estimated for the selection model indicate that the independent variables for whether or not the firm becomes an innovator have high joint explanatory power. The results, which are displayed in Appendix B, indicate that firm size has a significant effect on the probability of being an *innovator*. Based on this model, we calculated the *PINNOVATOR* variable, which is included in the second- stage models (Tables 5 and 6). Table 5 presents the estimations for process innovation; Table 6 presents the estimations for product innovation.

[Insert table 5 about here]

[Insert table 6 about here]

In general, it can be said that the econometric specifications have acceptable predictive power, with an overall percentage of accurate predictions higher than 68% in all cases. Chi-square values for the degrees of freedom in the models seem to indicate rejection of the null hypothesis that all parameters except the intersection, are equal to zero with a significance level of 1%.

*PINNOVATOR* is not significant in most cases and when it is excluded from the models, the main variables barely change.<sup>5</sup> Thus, the hypothesis of sample selection bias can be rejected.

Model 1 reports the baseline model including only the control variables and the external knowledge sourcing strategies. This model indicates that the effect of the different modalities of external knowledge acquisition on the firm's innovation performance varies, mainly depending on the type of innovation. The results for process innovation (Table 5) show that the acquisition of technological knowledge embodied in machinery and equipment (*EQ*) has the greatest impact. In the two sectoral categories analysed, the coefficients of the *EQ* variable are positive and highly significant, indicating that

purchase of machinery and equipment is an important strategy to develop new processes. In contrast, neither of the cooperation strategies has a significant effect. It is especially surprising that cooperation with industrial agents is not significant, bearing in mind that machinery and equipment suppliers are the industrial agents with which firms are more likely to cooperate (Tables 3 and 4).

These results show that in Spain, in contrast to other countries, the establishment of cooperation agreements with industrial agents does not enhance firms' production processes. For the UK, Freel (2003) and Reichstein and Salter (2006) found that the establishment of links with suppliers is important to enhance process innovation, especially for supplier-dominated firms. A likely explanation of our results is the low technological level of the firms in these sectors, for which process innovations mainly consist of minor incremental improvements achieved through the purchase of new machinery and equipment, with the supplier's role being reduced to the provision of this equipment.

For product innovation (Table 6), the effect of external knowledge sourcing strategies varies depending on the sectoral category. The acquisition of intangible technology (*TECNO*) and cooperation with industrial agents (*CI*) have a significant influence on supplier-dominated firms, while machinery and equipment acquisition (*EQ*) and cooperation with scientific agents (*CNI*) are the only strategies that are shown to have a positive and significant effect for science-based firms. Two important points emerge from these findings. First, cooperation is a useful strategy for the development of new products. Second, the choice of cooperation partners depends on the industrial sector. These results are consistent with the findings from other studies that show that the value of external factors to innovation may have been overestimated by the network approach (Sternberg, 2000; Oerlemans et al., 1998), and strongly indicate the importance of

cooperation in conditional terms. As Freel (2003, p. 762.) puts it: ‘certain types of cooperation are associated with specific types of innovation, involving certain firms, in certain sectors’. Likewise, contrary to expectations, R&D outsourcing (*ERD*) was not found to be significant, even for science-based firms. In fact, in most cases, the estimated coefficients of this variable were negative. This suggests that R&D contracting is not aimed at strengthening the firm’s innovative capacities as demonstrated by the services provided by universities to firms, which are mainly occasional activities with little scientific content.<sup>6</sup>

The effects of the firm’s internal capacities are introduced in model 2 through the variables *IRD* and *TRAINING*. The influence of these variables on firms’ innovative performance depends on the type of innovation, but is similar across sectoral categories. In-house R&D (*IRD*) has a significant influence on product innovation in the two sectoral categories, but its effect is not significant for process innovation. Internal training (*TRAINING*), on the other hand, significantly affects only process innovation.

Some additional comments are needed to clarify these results. The high significance of the *IRD* variable on product innovation highlights that far from losing relevance, implementation of in-house R&D activities is the main strategy for developing new products. On the other hand, it is hardly surprising that *IRD* was found to be not significant for process innovation. As mentioned in Section 3.3.2 studies on the effect of this variable on process innovation have produced mixed findings. In fact, our results coincide with those found by Freel (2003) for the UK. In any case, these findings highlight that in Spanish innovative firms with in-house R&D, these efforts are mainly directed towards product innovation. Improvements to the productive process are not based on either research or cooperation with external agents, but are largely driven by the purchase of machinery and equipment. Moreover, the acquisition of new machinery

and equipment usually requires some training of technical staff in how to use the new equipment, which explains the positive and significant effect of *TRAINING*.

In general, the inclusion of in-house R&D activities in the analysis has little effect on external knowledge sourcing strategies. Focusing on product innovation (where the *IRD* variable has a significant effect), only a change in the significance of the *CNI* variable is noted for science-based firms. This variable loses explanatory power when in-house R&D is considered, although it remains significant at 10%. In addition, the model 3 estimations show that the interactive term *CNI\*IRD* has a negative sign for science-based firms, although it is not significant. These results suggest that internal R&D efforts instead of promoting the exploitation of external scientific knowledge sources for innovation development, seem to reduce the importance of these types of sources for product innovation.

To summarize, our results do not support the complementarity hypothesis between internal knowledge development and external knowledge sourcing. However, given the insignificance of the interactive terms and the problems related to the interpretation of these terms in the logit models (Hoetker, 2007)<sup>7</sup>, we can not conclude that there are substitution effects between these strategies.

In any case, the above results differ from those in Cassiman and Veugelers (2006), but are closer to the findings in Laursen and Salter (2006) on the existence of substitution effects between in-house R&D and the openness of firm's external search strategies. Laursen and Salter explain these findings by the not-invented-here syndrome, which could be equally valid in our case. In-house R&D activities increase the firm's technological capacities leading the R&D team to believe that it has a monopoly of knowledge in the field. This makes firms resistant to the use of external ideas, especially those close to its core competences. These circumstance could lead the firm

to dismiss the need to cooperate with external agents or, alternatively, and as seems to have occurred in our case, to cooperate in activities not aimed at strengthening its innovative capabilities. This phenomenon is becoming more noticeable in the Spanish context, where scientific agents, especially universities, have not traditionally been considered to be important sources of knowledge for firms' innovative activities.<sup>8</sup> This argument is in line with Cassiman and Veugelers' (2006) finding that a firm's reliance on more 'basic' types of know-how affects the strength of the complementarity between innovation strategies. Thus, although firms that perform internal R&D on a continuous basis tend to cooperate more with universities relative to other external agents, this cooperation does not seem to be oriented towards the development of key activities for their innovation processes. This cooperation with scientific agents might be motivated more by access to funds through participation in government sponsored programmes, than to improving innovative capacities based on the integration of complementary knowledge from external agents.

The corollary that may be drawn from the above, is that the effectiveness of external knowledge sourcing strategies to encourage a firm's innovative performance depends not only on the acquisition of knowledge, but also on the firm's capability to set priorities and concentrate resources on the exploitation of relevant external knowledge. In this context, the distinction between potential (acquisition and assimilation of external knowledge) and realized (transformation and exploitation of external knowledge) absorptive capacity, introduced by Zahra and George (2002), becomes very important for analysing the dual role of in-house R&D.

We can also see that the influence of machinery and equipment acquisition and cooperation with industrial agents is the same in model 2 as in model 1, confirming that, unlike scientific knowledge sources, the effect of industrial knowledge sources on

innovation performance is largely dependent on the firm's internal technological capabilities. This is to be expected if we consider that the knowledge generated by in-house R&D activities, in principle, is different in nature from that generated through the purchase of machinery or cooperation with industrial agents. Also, as suggested by Cohen and Levinthal (1990), firms can access and exploit the knowledge generated by suppliers, competitors and customers with relative ease and, therefore, do not require a high level of internal technological competences.

Finally, we found that the *SIZE* variable was not significant in either process or product innovation; however, in the first-stage models firm size had a significant and positive effect for two of the sectoral categories analysed. This suggests that the effect of firm size is limited only to the decision to implement an innovation activity. Once the firm has decided to innovate, the probability that it will introduce new products or processes does not depend on size.

## **5. Conclusions**

The importance of external knowledge sourcing to a firm's innovation strategy has been addressed extensively in the recent literature. On the one hand, it has been established that firms are not self-sufficient with regard to technological resources and that they need to combine their capabilities with the capabilities that exist in other companies and institutions. On the other hand, following the notion of 'absorptive capacity', it has been shown that in-house R&D activities not only promote the use of external knowledge sources, but also increase a firm's capacity to exploit them efficiently for the development of new products and processes. To deepen our understanding of the role of external knowledge sources in enhancing firms' innovative performance, this study has

examined the effects of different external knowledge sourcing strategies on product and process innovation and to what extent these effects are influenced by in-house R&D. In our analysis we distinguished between external scientific and industrial knowledge sources and examined the possible moderating effects of industry dynamics, by considering two sectoral categories: supplier-dominated firms and science-based firms.

Some of our results are consistent with the literature, while others would indicate that the Spanish case is characterized by a number of distinctive features. In line with the literature, we found that the more technology-intensive the industry, the more frequent the cooperation with external agents, and especially with scientific agents such as universities and research centres. Likewise, in these sectors the implementation of R&D activities on a continuous basis is a more frequently observed strategy. These results are partially in line with the notion of absorptive capacity in the sense that the firms responsible for implementing in-house R&D are better placed to identify and acquire external knowledge (potential absorptive capacity).

However, unlike the findings from some studies, we found that product and process innovations may be independent of each other and, even more importantly, that they are associated with different knowledge sourcing strategies. For instance, our results indicate that process innovation is largely driven by the acquisition of knowledge ‘embodied’ in machinery and equipment and that cooperation with external agents has no significant effect. In contrast, cooperation seems to be an important strategy to develop new products, although its relevance varies depending on the nature of the partner and the sector in which the firm operates. It is, therefore, even more surprising that R&D contracting was found to be not significant in enhancing firms’ innovative performance for either of the sectoral categories, suggesting that the R&D services outsourced by firms are not aimed at strengthening their innovative capacities.

Although our results suggest that external knowledge acquisition can promote ideas and supply resources that help firms to improve their innovative performance, these results do not imply that such a strategy is either a necessary or sufficient condition for successful innovation, at least in the context analysed in this research. Our results indicate that in-house R&D activity still represents a strategic asset in the development of new products and, in addition, that developing and implementing these activities is significantly more important than employing strategies involving external partners.

Moreover, our analysis reveals another more fundamental issue. When we examined the relationships between external sourcing strategies and internal R&D, we found no evidence to support the complementarity hypothesis. In this sense, although internal R&D activities are associated with a greater use of external scientific knowledge sources (through cooperation), they do not seem to promote their exploitation for innovation development, that is to say, they do not have synergistic effects.

The results of this study have at least two important implications. Firstly, they support the idea that product innovation is a process that largely builds on the firm's internal capabilities, and warns against the risk of overrating external knowledge sourcing. In this regard, the influence of external knowledge sources on firms' innovative performance is likely to differ depending on several factors, such as type of sourcing strategy, type of knowledge source, the characteristics of the sector and the context in which the firm operates, and even the firm's internal capacities. Secondly, acceptance of this heterogeneity should lead policy makers in Spain and other technology follower countries, to acknowledge the complexity of the innovation process and avoid the promotion of 'one size fits all' mechanisms, which are generally only suited to the most technologically developed countries.



In Spain, those responsible for innovation policy have traditionally been guided by a linear vision of innovation, focusing in particular on strengthening the public research system. Recently, encouraging closer relations between firms and public institutions has become an objective of innovation policy, which could explain the relative importance of universities and research centres as cooperation partners. However, in the light of our results, it would appear that policy makers should concentrate on strengthening the technological capabilities of firms as it is these features that have the greatest influence on innovation. Also, in order to promote the transfer and exploitation of the knowledge generated by public research centres and universities, innovation policy should go beyond simple support for these relationships and establish mechanisms to enhance firms' reliance on the research conducted by these agents in order to promote cooperation in activities with a higher impact on innovation. These policies should be integrated with university and research centre policies, which, rather than indiscriminately promoting the commercialization of their knowledge and technological capabilities, should take account of the requirements of the sectors and firms being targeted.

We should point out that our study has some limitations, which might provide areas for future research. Firstly, the data employed are cross-sectional. The increase in firms' technological capacities derived from conducting in-house R&D in a  $t$  period can encourage the exploitation of external knowledge sources in a later period. In this sense, we believe that longitudinal data would improve the strength of the complementarity analysis by allowing implementation of more rigorous analytical methods and accounting for unobserved heterogeneity, which has been a major problem in the empirical studies of complementarities. This limitation is likely to be overcome when the innovation survey data for 2005 and 2006 become available in the PITEC database.

There are also many questions arising from this study that cannot be addressed without additional in-depth case studies. Identifying the firms' motivations for choosing among different strategies or identifying the obstacles to accessing different knowledge sources are two key issues that could be investigated by means of case studies. These would allow us to collect information on the strategies employed by firms to achieve specific projects and to analyse the complementarity between external knowledge acquisition and internal knowledge development at project level.

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## References

- Acs, Z.J. and Audretsch, D.B. (1988), 'Innovation in large and small firms: an empirical analysis', *American Economic Review*, 78, 678-690.
- Arora, A. and Gambardella, A. (1994), 'Evaluating technological information and utilizing it: Scientific knowledge, technological capability and external linkages in biotechnology', *Journal of Economic Behavior and Organization*, 24, 91-114.
- Arora, A. and Gambardella, A., (1990), 'Complementarity and external linkages: The strategies of the large firms in biotechnology' *Industrial Economics*, 38 361-379.
- Arundel, A., Van de Paal, G. and Soete, L. (1995), 'Innovation strategies of Europe's largest industrial firms', *PACE Report*. MERIT, University of Limbourg, Maastricht.
- Baptista, R. and Swann, P. (1998), 'Do firms in clusters innovate more?', *Research Policy*, 27, 525-540.
- Bayona, C., García, T. and Huerta, E. (2002), 'Collaboration in R&D with universities and research centres: an empirical study of Spanish firms', *R&D Management*, 32, 321-341.
- Becker, W. and Dietz, J., (2004), 'R&D cooperation and innovation activities of firms – evidence for the German manufacturing industry', *Research Policy*, 33, 209-223.

- Beneito, P. (2003), 'Choosing among alternative technological strategies: An empirical analysis of formal sources of innovation', *Research Policy*, 32, 693-713.
- Bönte, W. (2003), 'R&D and productivity: Internal vs external R&D – evidence from West German manufacturing industries', *Economics of Innovation and New Technology*, 12, 343-360.
- Breschi, S. and Malerba, F. (1997), 'Sectoral systems of innovation', In Edquist, C. (ed.), *Systems of Innovation*, Pinter: London.
- Cassiman, B. and Veugelers, R. (2006), 'In search of complementarity in innovation strategy: internal R&D and external knowledge acquisition', *Management Science*, 52, 68-82.
- Castro, E. and Fernández, I., (2006) 'La I+D empresarial y sus relaciones con la investigación pública española', in: Sebastián, J. and Muñoz, E. (eds), *Radiografía de la investigación pública en España*, Biblioteca Nueva: Madrid.
- Caloghirou, Y., Kastelli, I. and Tsakanikas, A. (2004), 'Internal capabilities and external knowledge sources: Complements or substitutes for innovative performance?', *Technovation*, 24, 29-39.
- Cesaratto, S. and Mangano, S. (1992), 'Technological profiles and economic performance in the Italian manufacturing sector', *Economics of Innovation and New Technology*, 2, 237-256.
- Chesbrough, H. (2003), 'The era of open innovation', *Sloan Management Review*, Summer, 35-41.
- Chesnais, F. (1996), 'Technological agreements, networks and selected issues in economic theory', in Coombs, R., Richards, A., Saviotti, P.P. and Walsh, V (eds),

*Technological Collaboration. The Dynamics of Cooperation in Industrial Innovation*, Edward Elgar: Cheltenham.

Cohen, W.M. and Levinthal, D.A. (1989), 'Innovation and Learning: The two faces of R&D', *The Economic Journal*, 99, 569-596.

Cohen, W.M. and Levinthal, D.A. (1990), 'Absorptive Capacity: A new perspective on learning and innovation', *Administrative Science Quarterly*, 35, 128-152.

Cohen, W. (1995), 'Empirical studies of innovative activity', in Stoneman, P. (ed.), *Handbook of the Economics of Innovation and Technological Change*, Blackwell: Oxford.

Cooke P. and Morgan, K. (1998), 'The creative milieu: a regional perspective on innovation', in Dodgson, M. and Rothwell, R. (Eds.), *The Handbook of Industrial Innovation*, Edward Elgar: Cheltenham.

Coombs, R. (1996), 'Core competences and the strategic management of R&D', *R&D Management*, 26, 345-355.

Croisier, B. (1998), 'The governance of external research: Empirical testing of some transaction-cost related factors', *R&D management*, 28, 289-298.

Edquist, C. (1997), *Systems of Innovation: Technologies, Institutions, and Organizations*. Pinter: London.

European Commission (2001), *European trend chart on innovation. Country report: Spain July 2000-December 2000*. Brussels: EC.

Evangelista, R. (1999), *Knowledge and Investment. The Sources of Innovation in Industry*, Edward Elgar: Cheltenham.

Freel, M. (2003), 'Sectoral patterns of small firm innovation, networking and proximity', *Research Policy*, 32, 751-770.

Freeman, C. (1991), 'Networks of innovators: a synthesis of research issues', *Research Policy*, 20, 499-514.

Gutiérrez, A., Fernández, I. and Manjarrés, L. (2007), 'Características de la demanda de I+D de las universidades de la Comunidad Valenciana', in: *La contribución de las universidades españolas al desarrollo*, Fundación CYD: Madrid.

Haas, M. and Hansen, M., (2005), 'When using knowledge can hurt performance: The value of organizational capabilities in a management consulting company', *Strategic Management Journal*, 26, 1-24.

Hagedoorn, J. (1993), 'Understanding the rationale of strategic technology partnering: interorganizational modes of cooperation and sectoral differences', *Strategic Management Journal*, 14, 371-385.

Hagedoorn, J. (2002), 'Inter-firm R&D partnerships: An overview of major trends and patterns since 1960', *Research Policy*, 31, 477-492.

Håkansson, H. (1987), 'Product development in networks', in Håkansson, H. (ed.), *Industrial Technological Development: A Network Approach*, Croom Helm: London.

Harabi, N. (1995), 'Appropriability of technical innovations: An empirical analysis', *Research Policy*, 24, 981-992.

Hoffman, K., Milady, P., Bessant, J. and Perren, L. (1998), 'Small firms, R&D, technology and innovation in the UK: A literature review', *Technovation*, 18, 39-55.

Hoetker, G. (2007), 'The use of logit and probit models in strategic management research: Critical issues', *Strategic Management Journal*, 28, 331-343.

Howells, J. (1999), 'Regional systems of innovation?', in Archibugi, D., Howells, J. and Michie, J. (eds), *Innovation Policy in a Global Economy*, Cambridge University Press: Cambridge.

Howells, J., Andrew, J. and Malik, K., (2003), 'The sourcing of technological knowledge: distributed innovation processes and dynamic change', *R&D Management*, 33, 395-409.

Kamien, M. and Schwartz, N. (1982), *Market structure and innovation*, Cambridge University Press: Cambridge.

Katz, R. and Allen, T., (1982), 'Investigating the not invented here (NIH) syndrome: A look at the performance, tenure, and communication patterns of 50 R&D projects', *R&D Management* 12, 7-19.

Kay, N. (1988), 'The R&D function: corporate strategy and structure', in Dosi, G., Freeman, C., Nelson, R, Silverberg, G. and Soete, L (eds), *Technological Change and Economic Theory*, Pinter: London.

Klevorick, A.K., Levin, R.C., Nelson, R.R. and Winter, S.G. (1995), 'On the sources and significance of interindustry differences in technological opportunities', *Research Policy*, 24, 185-205.

Laursen, K., Salter, A. (2006), 'Open for Innovation: The role of openness in explaining innovative performance among U.K. manufacturing firms', *Strategic Management Journal* 27, 131-150.

Lowe, J. and Taylor, P., (1998), 'R&D and technology purchase through licence agreements: Complementarity strategies and complementarity assets', *R&D Management*, 28, 263-278.

- Lundvall, B-Å. (ed.) (1992), *National Systems of Innovation: Toward a Theory of Innovation and Interactive Learning*, Pinter: London.
- MacPherson. A.D. (1997), 'A comparison of within-firm and external sources of product innovation', *Growth and Change*, 28, 289-308.
- Malerba, F. (2005), 'Sectoral systems. How and why innovation differs across sectors', in Fagerberg, J., Mowery, D. and Nelson, R. (eds), *The Oxford Handbook of Innovation*, Oxford University Press: Oxford.
- Manning, W.G, Duan, N. and Rogers, W.H., (1987), 'Monte Carlo evidence on the choice between sample selection and two-part models', *Journal of Econometrics*, 35, 59–82.
- March, J.G. (1991), 'Exploration and exploitation in organization learning', *Organization Science*, 2, 71–87.
- Marsili, O. (2001), *The Anatomy and Evolution of Technological change and industrial dynamics*, Edward Elgar: Cheltenham.
- Martinez-Ros, E. (2000), 'Explaining the decisions to carry out product and process innovations: the Spanish case', *Journal of High Technology Management Research*, 10(2), 223–242.
- Milgrom, P. and Roberts, J. (1990), 'The economics of modern manufacturing: Technology, strategy, and organization', *American Economic Review*, 80, 511-528
- Molero, J. and Buesa, M. (1996), 'Patterns of technological change among Spanish innovative firms: the case of the Madrid region', *Research Policy*, 25, 647-663.
- Mowery, D.C. (1983), 'The relationship between intrafirm and contractual forms of industrial research in American manufacturing, 1900-1940', *Exploration in Economics History*, 20, 351-374.



- Mowery, D.C. and Rosenberg, N., (1989), *Technology and the Pursuit of Economic Growth*, Cambridge University Press: Cambridge.
- Nelson, R. (2000), 'National innovation systems', in: Acs, Z. (ed.), *Regional Innovation, Knowledge and Global Change*, Pinter: London.
- Nelson, R. and Winter, S. (1982), *An Evolutionary Theory of Economic Change*, Belknap Press: Cambridge.
- Ocasio, W. (1997), 'Towards an attention-based view of the firm', *Strategic Management Journal*, Summer Special Issue 18, 187–206
- Oerlemans, L., Meeus, M. and Boekema, F. (1998), 'Do networks matter for innovation? The usefulness of the economic network approach in analysing innovation', *Tijdschrift voor Economische en Sociale Geografie*, 89, 298-309.
- Pavitt, K. (1984), 'Sectoral patterns of technical change', *Research Policy*, 13, 343-373.
- Pisano, G. (1989), 'Using equity participation to support exchange: Evidence from the biotechnology industry', *Journal of Law, Economics and Organization*, 5, 109.
- Pisano, G. (1990), 'The R&D boundaries of the firm: An empirical analysis', *Administrative Science Quarterly*, 35, 153.
- Reichstein, T. and Salter, A. (2006), 'Investigating the sources of process innovation among UK manufacturing firms' *Industrial corporate Change*, 15, 653-682.
- Robins, J. and Wiersema, M., (1995), 'A resource-based approach to the multi-business firm', *Strategic Management Journal*, 16, 277-300.
- Rothwell, R. (1992), 'Successful industrial innovation: Critical factors for the 1990s', *R&D Management*, 22, 221-239.

- Shing, K. (1997), 'The impact of technological complexity and interfirm cooperation on business survival', *Academy of Management Journal*, 40, 339–367.
- Spence, M. (1984), 'Cost reduction, competition and industry performance', *Econometrica*, 52, 101 - 121.
- Sternberg, R. (2000), Innovation networks and regional development – evidence from European Regional Innovation Survey (ERIS): Theoretical concepts, methodological approach, empirical basis and introduction to the theme issue', *European Planning Studies*, 8, 389-407.
- Teece, D.J. (1986), 'Profiting from technological innovation: implications for integration, collaboration, licensing and public policy', *Research Policy*, 15, 285–305.
- Teece, D.J. (1988), 'Technological change and the nature of the firm', in Dosi, G., Freeman, C., Nelson, R, Silverberg, G. and Soete, L (eds), *Technological Change and Economic Theory*, Pinter: London.
- Veugelers, R. (1997), 'Internal R&D expenditures and external technology sourcing', *Research Policy*, 26, 303-315.
- Veugelers, R. and Cassiman B., (1999), 'Make and buy in innovation strategies: Evidence from Belgian manufacturing firms', *Research Policy*, 28 63-80.
- Von Hippel, E. (1988), *The Sources of Innovation*, Oxford University Press: New York and Oxford.
- Wang, J.C., (1994), 'Cooperative research in a newly industrialized country: Taiwan', *Research Policy*, 23, 697–711.
- Williamson, O.E. (1985), *The Economic Institutions of Capitalism. Firms, Markets, Relational Contracting*, The Free Press: New York.

Zahra, S.A. and George, G., (2002), 'Absorptive capacity: a review, reconceptualization, and extension', *Academy of Management Review*, 27, 185-203.

## Tables

**Table 1.** Distribution of manufacturing firms in PITEC 2004 database

	Firms with fewer than 200 employees	Firms with 200 or more employees	TOTAL
Firms with intramural R&D expenditure	2259	745	3004
Firms with innovation expenditure but no intramural R&D expenditure	429	175	604
Firms without innovation expenditure	566	271	837
<b>TOTAL</b>	<b>3254</b>	<b>1191*</b>	<b>4445</b>

**Table 2.** Distribution of *innovator firms* by economic activity and sectoral classification. Data for PITEC sample and population in 2004

Pavitt's Category	Economic Activity	Sample	Sample (%)	Population	% Population
Supplier dominated firms	RUBBER AND PLASTICS	194	28.74	846	16.92
	TEXTILE	135	20	795	15.9
	FURNITURE	108	16	1200	24
	PAPER	53	7.85	383	7.66
	WOOD AND CORK	48	7.11	602	12.04
	LEATHER AND FOOTWEAR	42	6.22	303	6.06
	OTHER PRODUCTS	47	6.96	345	6.9
	CLOTHING AND FURS	33	4.89	471	9.42
	RECYCLING	15	2.22	54	1.08
	<i>Total</i>	<i>675</i>	<i>100</i>	<i>4999</i>	<i>100</i>
Science based firms	CHEMISTRY	400	61.16	840	67.25
	PHARMACEUTICAL PRODUCTS	124	18.96	178	14.25
	RADIO APPARATUS. TV AND COMMUNICATION	76	11.62	107	8.57
	ELECTRICAL COMPONENTS	36	5.5	95	7.61
	MANUFACTURE OF AIRCRAFT AND SPACECRAFT	18	2.75	29	2.32
	<i>Total</i>	<i>654</i>	<i>100</i>	<i>1249</i>	<i>100</i>

**Table 3.** Descriptive statistics and Spearman's correlation coefficients (supplier-dominated firms)

	Mean	S.D.	PRODIN	PROCIN	SIZE	ERD	EQ	TECNO	CI	CNI	IRD
PRODIN	0.665	0.472	1								
PROCIN	0.744	0.437	-0.057	1							
SIZE	16.020	1.476	0.07	0.012	1						
ERD	0.471	0.500	-0.003	0.078*	0.052	1					
EQ	0.496	0.500	0.051	0.257**	0.022	0.149**	1				
TECNO	0.138	0.345	0.092*	0.067	0.074	0.139**	0.179**	1			
CI	0.299	0.682	0.140**	0.110**	0.116**	0.239**	0.120**	0.055	1		
<i>C-Other firms</i>	0.058	0.233									
<i>C-Suppliers</i>	0.132	0.339									
<i>C-Clients</i>	0.068	0.252									
<i>C-Competitors</i>	0.041	0.200									
CNI	0.277	0.664	0.134**	0.104**	0.037	0.226**	0.035	0.041	0.504**	1	
<i>C-Labs and Private</i>											
<i>R&amp;D Institutes</i>	0.076	0.264									
<i>C-Universities</i>	0.059	0.236									
<i>C-Public Research</i>											
<i>Institutes</i>	0.034	0.182									
<i>C-Technology Centers</i>	0.108	0.311									
IRD	1.345	0.839	0.243**	-0.037	0.167**	-0.109**	-0.067	0.012	0.074	0.136**	1
IRD (1)	0.178										
IRD (2)	0.584										
TRAINING	0.422	0.494	0.111**	0.172**	0.098*	0.149**	0.351**	0.294**	0.185**	0.156**	0.112**

\*\* Correlation is significant at the 0.01 level (bilateral).

\* Correlation is significant at the 0.05 level (bilateral).

**Table 4.** Descriptive statistics and Spearman's correlation coefficients (science-based firms)

	Mean	S.D.	PRODIN	PROCIN	SIZE	ERD	EQ	TECNO	CI	CNI	IRD
PRODIN	0.777	0.417	1								
PROCIN	0.680	0.467	0.034	1							
SIZE	16.320	1.726	0.04	0.093*	1						
ERD	0.511	0.500	0.034	0.097*	0.262**	1					
EQ	0.457	0.499	0.123**	0.227**	0.052	0.180**	1				
TECNO	0.147	0.354	0.067	0.117**	0.230**	0.181**	0.218**	1			
CI	0.524	0.943	0.126**	0.093*	0.272**	0.241**	0.122**	0.206**	1		
<i>C-Other firms</i>	0.139	0.346									
<i>C-Suppliers</i>	0.148	0.356									
<i>C-Clients</i>	0.148	0.356									
<i>C-Competitors</i>	0.089	0.285									
CNI	0.642	1.117	0.130**	0.099*	0.244**	0.344**	0.115**	0.146**	0.512**	1	
<i>C-Labs and Private R&amp;D Institutes</i>	0.130	0.337									
<i>C-Universities</i>	0.245	0.430									
<i>C-Public Research Institutes</i>	0.130	0.337									
<i>C-Technology Centers</i>	0.138	0.345									
IRD	1.731	0.576	0.117**	-0.015	0.149**	0.049	-0.034	0.015	0.084*	0.118**	1
IRD (1)	0.135										
IRD (2)	0.798										
TRAINING	0.557	0.497	0.091*	0.200**	0.091*	0.124**	0.319**	0.266**	0.173**	0.184**	0.129**

\*\* Correlation is significant at the 0.01 level (bilateral).

\* Correlation is significant at the 0.05 level (bilateral).

**Table 5.** Determinants of process innovation, results of the regression analysis.

Independent variables	Supplier-dominated firms			Science-based firms		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
PINNOVATOR	0.55 (0.69)	0.67 (0.70)	0.67 (0.71)	0.92 (1.09)	0.92 (1.12)	1.02 (1.12)
SIZE	-0.01 (0.07)	-0.01 (0.07)	-0.01 (0.07)	0.06 (0.06)	0.07 (0.06)	0.07 (0.06)
ERD	0.09 (0.19)	0.03 (0.20)	0.15 (0.38)	0.16 (0.19)	0.16 (0.19)	-0.94 (0.60)
EQ	1.22*** (0.20)	1.08*** (0.21)	1.08*** (0.21)	0.90*** (0.19)	0.74*** (0.19)	0.69*** (0.20)
TECNO	0.17 (0.31)	0.01 (0.32)	0.01 (0.32)	0.48 (0.30)	0.31 (0.31)	0.29 (0.31)
CNI	0.35 (0.22)	0.34 (0.22)	-0.07 (0.44)	0.04 (0.10)	0.03 (0.10)	0.51 (0.53)
CI	0.16 (0.20)	0.14 (0.20)	0.39 (0.51)	0.06 (0.12)	0.04 (0.12)	0.37 (0.54)
IRD		-0.15 (0.12)	-0.12 (0.17)		-0.13 (0.16)	-0.36 (0.25)
TRAINING		0.48** (0.22)	0.49** (0.22)		0.61*** (0.19)	0.59*** (0.19)
IRD*ERD			-0.09 (0.24)			0.61 (0.33)
IRD*CNI			0.27 (0.26)			-0.26 (0.28)
IRD*CI			-0.16 (0.28)			-0.18 (0.28)
Industries dummies	Included	Included	Included	Included	Included	Included
Intercept	1.01 (1.15)	1.08 (1.16)	0.96 (1.19)	-1.13 (1.21)	-1.16 (1.22)	-0.89 (1.25)
Chi-squared (d.f)	67.82*** (16)	73.51*** (18)	74.67*** (21)	49.44*** (11)	59.95*** (13)	65.36*** (16)
Pseudo $R^2$	0.14	0.15	0.15	0.10	0.12	0.13
Observations	675	675	675	654	654	654

Data inside parenthesis are the corresponding standard errors

\*  $P < 0.1$ \*\*  $P < 0.05$ \*\*\*  $P < 0.01$

**Table 6.** Determinants of product innovation, results of the regression analysis.

Independent variables	Supplier-dominated firms			Science-based firms		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
PINNOVATOR	1.56** (0.62)	0.97 (0.64)	0.97 (0.64)	3.51*** (1.13)	3.01** (1.15)	2.94** (1.15)
SIZE	0.07 (0.06)	0.04 (0.06)	0.04 (0.06)	-0.04 (0.06)	-0.05 (0.06)	-0.05 (0.06)
ERD	-0.27 (0.18)	-0.12 (0.18)	-0.19 (0.31)	-0.03 (0.22)	0.03 (0.22)	0.27 (0.56)
EQ	0.11 (0.17)	0.17 (0.19)	0.16 (0.19)	0.54** (0.21)	0.58** (0.22)	0.59** (0.22)
TECNO	0.57** (0.27)	0.52* (0.29)	0.52* (0.29)	0.33 (0.33)	0.35 (0.34)	0.37 (0.34)
CNI	0.26 (0.18)	0.17 (0.18)	0.16 (0.36)	0.23** (0.12)	0.20* (0.12)	0.52 (0.47)
CI	0.34* (0.18)	0.31* (0.18)	0.49 (0.36)	0.19 (0.15)	0.20 (0.15)	0.01 (0.44)
IRD		0.53*** (0.11)	0.52*** (0.15)		0.51*** (0.16)	0.60** (0.24)
TRAINING		0.11 (0.20)	0.11 (0.20)		0.02 (0.22)	0.02 (0.22)
IRD*ERD			0.06 (0.21)			-0.15 (0.32)
IRD*CNI			0.01 (0.22)			-0.17 (0.25)
IRD*CI			-0.12 (0.22)			0.11 (0.24)
Industries dummies	Included	Included	Included	Included	Included	Included
Intercept	-1.94* (1.03)	-1.85* (1.05)	-1.85* (1.08)	-1.34 (1.30)	-1.53 (1.31)	-1.70 (1.33)
Chi-squared (d.f)	41.86*** (16)	68.80*** (18)	69.20*** (21)	43.57*** (11)	53.67*** (13)	54.51*** (16)
Pseudo $R^2$	0.08	0.13	0.13	0.10	0.12	0.12
Observations	675	675	675	654	654	654

Data inside parenthesis are the corresponding standard errors

\*  $P < 0.1$ \*\*  $P < 0.05$ \*\*\*  $P < 0.01$



## Appendix A. Description of the variables

Variable	Description	Scale of Measurement
PRODIN	Product innovation	Dummy variable: 1 if the firm developed or introduced new or improved products into the market during 2002-2004 period, and 0 otherwise
PROCIN	Process innovation	Dummy variable: 1 if the firm developed or introduced new or improved process into the market during 2002-2004 period, and 0 otherwise
SIZE	Firm's size	Logarithm of Firm's sales volume in 2004
ERD	Extramural R&D activities	Dummy variable: 1 if the firm was engaged in extramural R&D during 2002-2004 period, and 0 otherwise
EQ	Purchase of Machinery and equipment	Dummy variable: 1 if the firm was engaged in acquisition of machinery and equipment during 2002-2004 period, and 0 otherwise
TECNO	Acquisition of intangible technology in the form of patents, trademarks, software	Dummy variable: 1 if the firm was engaged in acquisition of external knowledge in the form of patents, non-patented inventions, licenses, disclosures of know-how, and 0 otherwise
C-Other firms	Cooperation with other firms of the same group in R&D and innovation activities during the period 2002-2004	Dummy variable: 1 if the firm has cooperated with this agent, and 0 otherwise
C-Clients	Cooperation with clients in R&D and innovation activities during the period 2002-2004	Dummy variable: 1 if the firm has cooperated with this agent, and 0 otherwise
C-Suppliers	Cooperation with suppliers in R&D and innovation activities during the period 2002-2004	Dummy variable: 1 if the firm has cooperated with this agent, and 0 otherwise
C-Competitors	Cooperation with competitors in R&D and innovation activities during the period 2002-2004	Dummy variable: 1 if the firm has cooperated with this agent, and 0 otherwise
CI	Addition of scores given to C-Other firms, C-Clients, C-Suppliers, C-Competitors	Values from 0 and 4
C-Labs and Private R&D firms	Cooperation with laboratories and R&D firms in R&D activities and innovation during the period 2002-2004	Dummy variable: 1 if the firm has cooperated with this agent, and 0 otherwise
C-Universities	Cooperation with universities in R&D activities and innovation during the period 2002-2004	Dummy variable: 1 if the firm has cooperated with this agent, and 0 otherwise
C-Public Research Institutes	Cooperation with public research bodies in R&D activities and innovation during the period 2002-2004	Dummy variable: 1 if the firm has cooperated with this agent, and 0 otherwise
C-Technology centres	Cooperation with technology centres in R&D activities and innovation during the period 2002-2004	Dummy variable: 1 if the firm has cooperated with this agent, and 0 otherwise
CNI	Addition of scores given to C- Labs and Private R&D firms C-Universities, C-Public Research Institutes, C-Technology centres	Values from 0 to 4
IRD	In-house R&D activities	0: The firm was not engaged in-house R&D activities during 2002-2004 period 1: The firm was engaged in-house R&D activities during 2002-2004 period, but only occasionally 2: The firm performed in-house R&D activities on a continuous basis during 2002-2004
TRAINING	Training activities oriented towards innovation	Dummy variable: 1 if the firm has carried out training activities during the period 2002-2004, and 0 otherwise
EXPORT	Export intensity	sales from exports/total sales

FACcost	Importance of cost obstacle for innovation by the firm: lack of funds in the firm; no suitable financing available outside the firm; high cost of innovation	Mean value of scores given to different factors from 1 (no important) to 4 (high importance).
FACknow	Importance of lack of technological/market information for innovation by the firm: lack of qualified personnel; lack of information about technology; lack of information about market; lack of adequate partners	Mean value of scores given to different factors from 1 (no important) to 4 (high importance).
FACmark	Importance of market factors for innovation by the firm: market dominated by established firms; uncertainty about the demand for innovative products and services	Mean value of scores given to different factors from 1 (no important) to 4 (high importance).
FACneed	Importance of no need for innovation as an obstacle for innovation by the firm: no need for innovations because of earlier innovations; little interest for innovations by customers	Mean value of scores given to different factors from 1 (no important) to 4 (high importance).
GROUP	The firm belongs to a group	Dummy variable: 1 if the firm belongs to a group, and 0 otherwise

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## Appendix B. Results for first-stage model (dependent variable = *INNOVATOR*)

Independent Variables	Supplier-dominated firms	Science-based firms
SIZE	0.18*** (0.07)	0.19* (0.11)
EXPORT	0.01*** (0.00)	0.00 (0.01)
GROUP	-0.06 (0.16)	-0.24 (0.22)
FACcost	0.40*** (0.12)	0.13 (0.18)
FACknow	0.08 (0.15)	0.42 (0.28)
FACmark	0.33** (0.12)	0.62*** (0.21)
FACneed	-0.78*** (0.10)	-1.10 *** (0.19)
Industries dummies	Included	Included
Intercept	-2.25* (1.16)	-2.71 (1.84)
Chi-squared (d.f)	167.95*** (16)	75.56*** (11)
Pseudo $R^2$	0.25	0.22
Observations	901	720
Data inside parenthesis are the corresponding standard errors		
* $P < 0.1$		
** $P < 0.05$		
*** $P < 0.01$		

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<sup>1</sup> Although the data come from a panel of firms, we carry out a cross-sectional rather than a longitudinal analysis. This is because currently PITEC only provides information for two years (2003 and 2004). The 2003 sample has an important methodological limitation. For reasons of opportunity and viability, PITEC started with only two samples in 2003: a sample of firms with 200 or more employees and a sample of firms with intramural R&D expenditure. Thus, firms with fewer than 200 employees, with no in-house R&D activities, but which engage in innovation were excluded for 2003.

<sup>2</sup> This is not to say that service firms (as users of technology developed in other sectors) have a passive attitude to innovation; it means only that as the nature of the innovative processes varies substantially between manufacturing and service firms (Hoffman et al., 1998) we do not consider it appropriate to analyse them jointly.

<sup>3</sup> These interactive terms indicate how the effect of external knowledge sources on the innovation outcome varies when the *IRD* variable is modified by 1 unit.

<sup>4</sup> According to Eurostat data based on CIS-4.

<sup>5</sup> We estimated the second-stage models excluding the *PINNOVATOR* variable. The parameters of the main variables changed very little compared to those shown in Tables 6 and 7. The estimations are available from the authors upon request.

<sup>6</sup> E.g., if we consider the case of the universities located in the Autonomous Community of Valencia, out of the 12,121 contracts between universities and private businesses in the period 1999-2004, 40% were for the provision of services, 40% were for technological support and only 14% were R&D agreements (Gutierrez et al., 2007).

<sup>7</sup> Hoetker (2007) pointed out that due to the non-linear nature of logit models the marginal effect of interaction effect between two variables is not simply the coefficient of their interaction. This effect is also a function of the coefficients of each interacted variable and the different values of all covariates. In this sense, neither the sign nor the significance of the interaction coefficient may indicate the direction and the significance of the interaction effect.

<sup>8</sup> E.g., only 2.4% of innovator firms in the supplier-dominated firm category, and 13% in the science-based firm category, report universities as being important knowledge sources for innovative activity.